Research Square

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Mobilizing collaboratively generated ecological knowledge for community-based birdwatching

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Abstract

Participatory ecological research fosters collaboration between researchers and local communities, but collaboratively generated knowledge does not automatically translate into resources for community-led environmental initiatives. We investigated how ecological knowledge generated through participatory research was mobilized to support a community-based birdwatching initiative in a fishing community in northeastern Brazil. Community members contributed local ecological knowledge to bird surveys by indicating trails, assisting bird detection, and sharing information on species occurrence, habitat use, behavior, and local bird names. Beta diversity analyses assessed compositional complementarity among sampled habitats, while subsequent community applications of the generated knowledge were documented. Community-indicated trails were incorporated into ecological surveys, and beta diversity analyses revealed complementary bird assemblages across phytophysiognomies. Collaboratively generated knowledge was subsequently mobilized through the establishment of birdwatching routes, training of local guides, and continued activities in environmental education and nature-based tourism. The participatory process also supported the development of guiding skills among participating residents and the documentation of local bird names and ecological knowledge. Our findings provide empirical evidence that collaboratively generated ecological knowledge can support community-based environmental initiatives. More broadly, integrating local ecological knowledge with ecological analyses can strengthen connections between biodiversity research and community-led environmental action while creating opportunities for sustainable birdwatching.

Introduction

Birdwatching has attracted increasing attention as a form of nature-based tourism, with growing participation and economic relevance in different regions (Cordell & Herbert, 2002; Steven et al., 2015). As a specialized form of ecotourism, birdwatching has attracted considerable attention because it can simultaneously promote biodiversity conservation and sustainable rural development (Şekercioğlu, 2002; Stronza et al., 2019; Schwoerer & Dawson, 2022). Realizing these multiple benefits depends, however, not only on providing ecologically rewarding birdwatching experiences, but also on ensuring that conservation and tourism benefits are effectively shared with local communities (Büscher & Fletcher, 2019; Massarella et al., 2023). Birdwatching may also create economic incentives for habitat protection and opportunities for local employment and income through guiding services and other tourism-related activities (Biggs, 2013; Hunt et al., 2015; Schwoerer & Dawson, 2022).

Achieving these ecological and social outcomes requires addressing two complementary challenges. First, birdwatching initiatives must create ecologically rewarding experiences capable of attracting visitors through careful planning, including the identification of attractive birdwatching sites, investment in infrastructure, and local capacity building (Kronenberg, 2014; Echeverri et al., 2022; Ocampo-Peñuela et al., 2025). Second, they require approaches that enable local communities to contribute their knowledge, participate meaningfully in the development of birdwatching initiatives, and access opportunities associated with nature-based tourism (Massarella et al., 2022). Because many

birdwatchers exhibit a species-collecting profile, seeking opportunities to observe species they have not previously recorded, networks of sites containing complementary bird assemblages may provide more attractive birdwatching experiences than itineraries based solely on species-rich locations (Hvenegaard, 2002; Connell, 2009).

Addressing the first challenge requires understanding how bird assemblages vary across landscapes. Conservation planning has traditionally relied on species richness (α diversity) to identify priority areas because it provides a straightforward measure of local biodiversity (Scott et al., 1993; Fleishman et al., 2006). Species richness and other ornithological indicators have also been used to identify suitable birdwatching sites and support tourism route planning (Istomina et al., 2016; Mamede & Benites, 2020). However, species richness alone does not capture differences in species composition among sites and may therefore overlook habitats that contribute unique components of regional biodiversity (Jetz & Rahbek, 2002; Fleishman et al., 2006; Socolar et al., 2016). In contrast, β diversity quantifies variation in species composition among sites, providing a basis for identifying habitats that contribute different components of regional biodiversity (Whittaker, 1960; Socolar et al., 2016; Liang et al., 2026). In this context, β-diversity analyses can provide complementary ecological information for birdwatching planning by highlighting differences in species composition among habitats that may not be apparent from species richness alone (Ferrier et al., 2007; Liang et al., 2026).

Yet generating ecological knowledge does not, by itself, ensure its application in community-based birdwatching initiatives. Understanding this relationship requires considering how local residents participate in knowledge production and how information generated through research can be used in local birdwatching, environmental education, and tourism activities (Norström et al., 2020; Padilla-Delgado et al., 2025).

Previous studies have shown that participatory ornithological research can contribute to both biodiversity assessment and locally relevant activities. In southern Mexico, community-based bird monitoring programs trained local residents, some of whom subsequently applied their skills as bird guides, in environmental education, and in ecotourism initiatives (Ortega-Álvarez et al., 2012). Further research in Mexican Indigenous communities documented how knowledge gained through bird monitoring supported the development of birdwatching routes and guiding services (Ortega-Álvarez & Calderón-Parra, 2021). Beyond these practical applications, the scientific quality of ecological information generated through participatory monitoring also needs to be considered. Mendoza-Lozana et al. (2025) demonstrated that community monitoring data could detect broad differences in bird species richness and diversity between forested and human-modified habitats, despite underestimating richness and abundance relative to professional ornithological surveys.

Although previous studies have documented important scientific contributions and community applications, examining how participatory ornithological research connects with pre-existing community priorities and how the ecological knowledge generated is subsequently mobilized and used can provide a more integrated understanding of its contributions to community-based birdwatching initiatives over

time. Participatory approaches can involve local communities at different stages of research, allowing their knowledge, experiences, and priorities to inform the research process (Haklay, 2013; Newing et al., 2024). In this context, knowledge mobilization provides a framework for examining how ecological knowledge is exchanged, adapted to locally relevant activities, and put into practice (Reed et al., 2014; Nguyen et al., 2017; Djenontin & Meadow, 2018).

In this study, we investigated how ecological knowledge generated through participatory ornithological research was mobilized to support a community-based birdwatching initiative in a coastal fishing community in northeastern Brazil. Specifically, we documented how local residents became involved in and contributed to ornithological surveys, assessed the ecological complementarity of bird assemblages across sampled habitats using beta diversity analyses, and examined how ecological knowledge was subsequently applied in birdwatching routes, local guide training, environmental education, and tourism activities. Drawing on research activities and follow-up observations spanning 2017–2026, we examined the applications of ecological knowledge beyond the initial surveys.

Methods

Study area

The study was conducted in the municipality of Conde, on the northern coast of Bahia, northeastern Brazil, within the Atlantic Forest biome. The participatory component involved residents of Siribinha, a fishing community whose livelihoods are linked to fishing and boat-related activities. The region comprises a heterogeneous landscape including mangroves, *restinga* (coastal shrub vegetation), and ombrophilous forest, which represent the principal phytophysiognomies of the northern coast of Bahia (Nogueira & Dominguez, 2007).

Bird surveys were conducted in representative and relatively well-conserved remnants of each phytophysiognomy (Fig. 1). Mangrove and *restinga* habitats were sampled within the Itapicuru River estuary (2,649 ha), one of the best-preserved mangrove systems on the northern coast of Bahia (Mantovani et al., 2019). To represent the ombrophilous forest phytophysiognomy, surveys were conducted in two Atlantic Forest remnants: the Bu Farm Legal Reserve (1,129 ha) and Mata do Timbó (approximately 1,829 ha). These remnants were selected because they represent the principal forest formations of the region, are among the best-preserved Atlantic Forest remnants in northern Bahia, and are located near the Conde-Baixios Important Bird and Biodiversity Area (IBA), a landscape recognized for the conservation of threatened and near-threatened Atlantic Forest endemic birds (BirdLife International, n.d.).

Participatory research design

The study combined ecological surveys with participatory activities at different stages. The approach sought to foster dialogue, integrate local expertise, and recognize complementary roles; participation

varied according to the objectives of each stage (Reed, 2008; Bollettin et al., 2023; Newing et al., 2024). An introductory birdwatching workshop in August 2017 presented birdwatching principles, discussed its potential as conservation-compatible nature-based tourism, and explored residents' perspectives and interest in further participation (De La Rosa et al., 2024). Interested residents were invited to join subsequent surveys and receive local-guide training after fieldwork.

Because the first campaign preceded the workshop, community input informed only subsequent surveys. Volunteers accompanied fieldwork, indicated trails and bird occurrence areas incorporated into sampling, assisted bird detection, and shared knowledge of species occurrence, habitat use, bird behavior, and local names. Local knowledge informed sampling, while standardized survey procedures and species identification remained the responsibility of the research team (Lawrence et al., 2006; Conrad & Hilchey, 2011; Danielsen et al., 2014). Following the final campaign in May 2018, interested residents received training in bird identification and vocalizations, birdwatching ethics, responsible playback, and organizing and pricing guiding services. Participants received field guides, binoculars, and an illustrated promotional booklet with species information, itineraries, guide contacts, and service fees. Further training in 2019 reinforced guiding practices and included first aid.

Participant observation of workshops, surveys, guide training, and follow-up visits was recorded in a field notebook (DeWalt & DeWalt, 2011). Follow-up notes (2017–2026) documented trail use for school environmental education, visits by birdwatching operators, guiding by trained residents, and continued use of the promotional booklet. Researchers also facilitated workshops, surveys, and guide training (Norström et al., 2020).

Analysis of knowledge mobilization

We chronologically reviewed field-notebook records of participant observation and post-project activities, alongside ecological survey results, to reconstruct how community members applied the knowledge generated. Following a narrative approach to process data (Langley, 1999; Lerman et al., 2022), we compared evidence across the workshop, participatory surveys, guide training, and subsequent birdwatching, environmental education, and guiding activities. For each stage, we considered its timing, actors involved, ecological information used, and evidence of implementation. This approach examined knowledge mobilization as an iterative process connecting ecological research, community engagement, capacity building, and practical action, rather than linear knowledge transfer (Djenontin & Meadow, 2018; Nguyen et al., 2017). Figure 2 summarizes the analytical pathway.

Bird surveys

Bird assemblages were sampled using the MacKinnon list method, with ten species per list (Bibby et al., 2000; MacLeod et al., 2011). Surveys were conducted by teams of two to three experienced observers using binoculars (8×42 and 10×42), digital audio recorders, and photographic equipment. Species were

identified visually and acoustically based on observer expertise and field guides (Ridgely & Gwynne, 2016; Sigrist, 2014). Sampling was carried out during four field campaigns between June 2017 and May 2018, encompassing all seasons to account for temporal variation in bird assemblages (Bibby et al., 2000). Each campaign lasted five consecutive days.

Surveys were conducted during periods of greatest bird activity, with four-hour morning sessions beginning before sunrise and three-hour afternoon sessions beginning at 15:00 (Bibby et al., 2000). Survey duration and timing were balanced across phytophysiognomies, with ombrophilous forest effort equally distributed between Bu Farm Legal Reserve and Mata do Timbó. MacKinnon lists were recorded continuously, totaling 140 hours (35 per campaign), although list numbers varied slightly among phytophysiognomies and seasons (Table S1). Species nomenclature followed the Brazilian Ornithological Records Committee (Piacentini et al., 2015); conservation status followed IUCN (2026).

Statistical analyses

Sampling completeness was evaluated using species accumulation curves and the Chao2 richness estimator based on incidence data from MacKinnon lists (Chao, 1987; Colwell et al., 2012). To examine differences in bird assemblage composition among mangrove, *restinga*, and ombrophilous forest, species occurrence data obtained from MacKinnon lists were used to calculate pairwise Sørensen dissimilarity. For these analyses, records from the two ombrophilous forest remnants were pooled within each sampling campaign to represent a single forest assemblage. Species records were aggregated by phytophysiognomy and sampling campaign, resulting in 12 assemblages for multivariate analyses. Variation in community composition among phytophysiognomies was explored using Principal Coordinates Analysis (PCoA) and similarities among habitats were further assessed through hierarchical clustering using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA). Ordination and clustering were used descriptively to visualize patterns of compositional dissimilarity among habitats and sampling campaigns.

To determine whether differences in community composition were primarily driven by species replacement or by differences in species richness, total beta diversity (Sørensen dissimilarity) was partitioned into its turnover and nestedness components following the framework proposed by Baselga (2010). Pairwise comparisons among mangrove, *restinga*, and ombrophilous forest were used to quantify the relative contribution of each component to compositional dissimilarity. Seasonal comparisons within each phytophysiognomy were also examined to evaluate temporal variation in community composition. All statistical analyses were performed in R version 4.1.0 (R Core Team, 2021), using the packages vegan (Oksanen et al., 2020) for multivariate analyses and betapart (Baselga & Orme, 2012) for beta diversity partitioning.

Results

Participatory research and knowledge mobilization

Participant observation and field notes documented that, following the introductory birdwatching workshop conducted in August 2017, five community members expressed interest in continuing to participate in the project. Of these, three voluntarily joined the subsequent ecological surveys and remained actively involved throughout the fieldwork and guide training activities. Their participation emerged spontaneously after discussions about the ecological, educational, and economic potential of birdwatching.

During the subsequent ecological surveys, community members accompanied different stages of the field campaigns, identified trails and bird occurrence areas that were incorporated into the sampling design, and assisted researchers in locating birds during fieldwork. Local ecological knowledge informed trail selection, facilitated bird detection, and contributed information on species occurrence, habitat use, behavior, and the local names used for bird species during the ecological surveys. Researchers, in turn, contributed taxonomic identification and ecological information, creating a continuous exchange between local ecological knowledge and scientific knowledge throughout the inventory process. One of the routes identified during this process, the *Porto do Saruê* trail, was subsequently adopted as the main birdwatching trail used by the community.

After the ecological surveys and analyses were completed in May 2018, the ecological knowledge generated during the study, including the bird inventory, information on species occurrence, and the birdwatching routes identified during the ecological surveys, formed the basis of the training of local bird guides. The three community members who had participated throughout the ecological surveys completed training in bird identification, bird vocalizations, birdwatching ethics, responsible use of playback, and practical aspects of organizing and pricing guiding services. To support the establishment of the community birdwatching initiative, participants received an illustrated promotional booklet developed from the ecological surveys, presenting photographs and information on bird species recorded in the study area together with descriptions of birdwatching itineraries, guide contacts, and service fees (Figure S2). Participants also received a regional bird identification guide (Sigrist, 2014) and binoculars to support bird identification during guiding activities. They subsequently completed additional first aid training organized by the Municipality of Conde and were formally recognized as local birdwatching guides. Two guides remained active after the training because one participant reported limited availability owing to other work commitments.

Following the bird surveys, research follow-up visits between 2018 and 2026 documented the use of birdwatching trails through field-notebook records. The *Porto do Saruê* trail was used for environmental education activities with local schools, where birdwatching was used as a tool for promoting awareness of local biodiversity. The two specialized birdwatching companies operating in the region, Brazil Birding Experts and Field Guides Tours, incorporated the trail into their itineraries and continued to hire the local guides trained through the project during visits to the study area. The promotional booklet developed during the project continued to be used to advertise the community birdwatching service and its

itineraries (Figure S2). Together, these records indicate that the ecological knowledge generated during the research continued to be applied through local birdwatching activities, environmental education, and professional guiding services (Fig. 2). The participatory ecological surveys also generated a comprehensive inventory of bird assemblages across the three sampled phytophysiognomies, providing the basis for the ecological analyses presented below.

Bird assemblages across phytophysiognomies

A total of 160 bird species were recorded across all sampling campaigns using the MacKinnon list method. Species richness varied among phytophysiognomies, with ombrophilous forest supporting the highest richness (95 species), followed by *restinga* (78 species) and mangrove (75 species) (Table S1).

Species composition also differed markedly among habitats. Ombrophilous forest contained the highest proportion of exclusive species (46%), whereas *restinga* exhibited the greatest proportion of species shared with the other phytophysiognomies (53%). Only 23 species were recorded across all three habitats, indicating limited overlap in bird assemblages.

The ombrophilous forest also harboured the greatest number of species of conservation concern, including Atlantic Forest endemics and globally threatened taxa such as *Pyriglena atra* (EN), *Xipholena atropurpurea* (VU), *Amazona rhodocorytha* (EN), *Herpsilochmus pileatus* (VU), *Touit surdus* (VU), and *Automolus lammi* (VU). Mangrove and *restinga* supported fewer threatened species but also contained species of conservation interest, including *Pyrrhura griseipectus* (EN), *Buteogallus aequinoctialis* (NT), and *Herpsilochmus pectoralis* (VU) (IUCN, 2026).

Rarefaction curves approached asymptotes for all phytophysiognomies, indicating adequate sampling effort (Figure S1). The Chao2 estimator indicated sampling completeness of 77% for mangrove, 76% for *restinga*, and 73% for ombrophilous forest, suggesting that most undetected species were likely rare taxa.

Beta diversity among phytophysiognomies

Ordination based on Sørensen dissimilarity revealed clear separation among mangrove, *restinga*, and ombrophilous forest bird assemblages, indicating pronounced differences in community composition among phytophysiognomies (Fig. 3). Seasonal variation was comparatively limited, with samples clustering primarily according to habitat type rather than sampling period. This pattern was further supported by the UPGMA analysis, which also grouped samples according to phytophysiognomy rather than season (Fig. 3).

Partitioning of Sørensen dissimilarity showed that beta diversity among phytophysiognomies was overwhelmingly dominated by species turnover, whereas nestedness contributed only a small proportion of total compositional dissimilarity (Fig. 3). Turnover values were consistently high, particularly between

ombrophilous forest and *restinga*, indicating that differences among habitats were primarily driven by species replacement rather than by nested subsets of species assemblages.

These results indicate that mangrove, restinga and ombrophilous forest support complementary bird assemblages because differences among habitats were driven predominantly by species turnover rather than by variation in species richness alone. Consequently, each phytophysiognomy contributed unique components of the regional avifauna.

Discussion

Our study suggests that ecological knowledge generated through participatory research can support community-based birdwatching initiatives through the development of local guiding skills, birdwatching routes, and subsequent applications in environmental education and nature-based tourism. In southern Mexico, Ortega-Álvarez et al. (2012) documented how community-based bird monitoring programmes developed local capacities that were subsequently applied to bird guiding, ecotourism, and environmental education, although implementation varied among regions. Similarly, Ortega-Álvarez and Calderón-Parra (2021) described how bird monitoring contributed to the development of birdwatching routes and guiding services in Indigenous communities, highlighting the potential reciprocal benefits of integrating monitoring and ecotourism. Our study adds a long-term perspective by examining how ecological knowledge generated through participatory research became incorporated into locally implemented birdwatching activities and continued to be used beyond the formal research period.

Examining these relationships is particularly relevant to discussions on how collaboration between scientific and local knowledge holders can connect ecological research with locally meaningful environmental practices (Tengö et al., 2014; Toomey et al., 2017; De La Rosa et al., 2024). In our study, the introductory birdwatching workshop provided an opportunity to discuss the ecological, educational, and economic potential of birdwatching with community members, five of whom expressed interest in further participation. Three subsequently joined the bird surveys, contributing local knowledge of bird occurrence and trails that informed the fieldwork and were later incorporated into birdwatching activities. The knowledge and skills developed through these interactions were subsequently applied in guide training, environmental education, and birdwatching services, including opportunities for local guides to work with external tour operators. An illustrated booklet containing bird records, birdwatching itineraries, and guide contact information also remained in use to promote these services (Figure S2). Rather than representing a linear transfer of scientific information, this process illustrates how ecological knowledge can be exchanged and mobilized through successive interactions between researchers and community members, consistent with conceptual frameworks linking knowledge production to practical action (Nguyen et al., 2017; Margules et al., 2020).

One relevant outcome of the participatory process was the incorporation of community-indicated trails into the sampling design, demonstrating how local knowledge can contribute to the selection of ornithological survey sites. Dixon et al. (2024) integrated Indigenous knowledge and ecological

modelling to select survey sites and identify areas of occurrence of the threatened bird *Amytornis woodwardi* in northern Australia. Their findings highlight how community participation in site selection can not only guide ecological surveys but also help identify areas of conservation importance for threatened species, a contribution that is also relevant to our study. Similarly, the study area yielded records of eight threatened bird species (EN or VU), considering the original inventory as a whole. Among these, the Endangered Grey-breasted Parakeet (*Pyrrhura griseipectus*; IUCN, 2026) is particularly noteworthy, having been recorded at Porto do Saruê, one of the locations identified by community members and subsequently incorporated into birdwatching routes. These records were particularly important because they documented the species' occurrence in Bahia, extending its previously known recent distribution beyond Ceará and revealing its use of coastal habitats, including mangroves and restinga vegetation (Félix et al., 2022). Although ombrophilous forest supported the highest species richness, differences in assemblage composition showed that mangrove and restinga contributed distinct components of the regional avifauna. Given the importance of beta diversity for identifying complementary habitats in biodiversity planning (Ferrier et al., 2007; Liang et al., 2026), these differences may also inform birdwatching itineraries that consider criteria beyond species richness. Because many birdwatchers seek opportunities to record species not previously included on their life lists, itineraries encompassing habitats with distinct bird assemblages may offer opportunities to observe a broader variety of species than routes focused exclusively on species-rich environments (Hvenegaard, 2002; Connell, 2009).

Beyond its potential application to birdwatching itinerary planning, habitat complementarity also has implications for biodiversity conservation. The predominance of species turnover over nestedness indicates that differences in assemblage composition were primarily driven by species replacement among habitats rather than differences in species richness alone (Baselga, 2010; Socolar et al., 2016). Because habitat complementarity is a central principle of systematic conservation planning (Margules & Pressey, 2000), these findings reinforce the importance of considering habitats with distinct bird assemblages when identifying conservation priorities, even when they support lower species richness (Pollock et al., 2017; Socolar et al., 2016). In the study region, where the surveyed forest remnants occur near the Conde-Baixios Important Bird and Biodiversity Area (IBA; Fig. 1), this perspective highlights the potential contribution of surrounding mangrove and restinga habitats to regional bird diversity. This interpretation is also consistent with recent recommendations emphasizing the importance of integrating ecological information into birdwatching development and conservation planning (Félix et al., 2025).

Beyond the ecological contributions, the continuity of activities developed through the research can also be considered in relation to how community involvement evolved throughout the initiative. The spontaneous involvement of residents following the introductory workshop may have facilitated their initial participation, although it does not, by itself, explain the subsequent continuity of these activities. West et al. (2026) found that initial participation in a community-based conservation programme in Tanzania reflected the alignment between participants' values and the programme's objectives, whereas continued engagement was increasingly associated with relationships developed over time. Similarly,

Larson et al. (2020) found that contributions to science and conservation were more frequently reported as a primary motivation for continuing participation than for initially joining a bird-monitoring programme. In Siribinha, two trained guides remained active, while a third reported limited availability due to other work commitments, indicating that continued involvement was not uniform among participants.

The subsequent hiring of local guides by external birdwatching tour operators also represents an important outcome of this process, demonstrating that the knowledge and skills developed during the research found practical application in professional tourism activities. In similar initiatives in South Africa, Biggs et al. (2011) identified economic benefits for community-based guides but found that these outcomes were associated not only with training but also with continued support for promotion, organisation, and access to tourism markets. This experience highlights the relevance of our training programme, which addressed not only bird identification and ethical birdwatching practices but also the organisation and pricing of guiding services, providing residents with practical guidance for valuing their work and negotiating with tour operators. However, these commercial relationships also require attention to contractual conditions and the autonomy of local service providers. Duong et al. (2026), for example, found that local participation in an ecotourism initiative in Vietnam coexisted with private company control over decision-making and an unequal distribution of benefits. Thus, although the hiring of local guides in Siribinha demonstrates concrete opportunities for professional participation, it does not establish whether the guides gained greater control over commercial arrangements or whether their remuneration was equitable.

Community participation throughout the bird surveys also provided an opportunity to document the local names used for bird species. Although local guides became familiar with the nomenclature commonly used by birdwatchers, the participatory process also enabled researchers to recognize and record the vernacular names traditionally used within the community. The researchers also emphasized the importance of preserving these local names rather than replacing them with names used in other parts of the country or with scientific names. This finding is consistent with biocultural approaches that recognize local classification systems and traditional ecological knowledge as integral components of biological and cultural diversity (Maffi, 2005; Berkes, 2012; Ludwig & El-Hani, 2020, 2025).

Although birdwatching activities continued beyond the research period, our study did not assess how decisions about the initiative were made or how tourism benefits were distributed. This distinction is important because participation in ecotourism does not necessarily translate into greater local control or an equitable distribution of benefits (Schellhorn, 2010; Coria & Calfucura, 2012). These issues are also central to the Convivial Conservation framework, particularly the findings of Ochieng et al. (2023), who highlighted how institutional arrangements and power relations can be more influential than the choice of conservation instrument in shaping social and ecological outcomes (Büscher & Fletcher, 2020; Massarella et al., 2023). Future research could examine how local guides participate in decision-making, negotiate their relationships with external tour operators, and benefit economically from birdwatching

activities. Such evidence would help determine whether the documented continuity of these activities has also translated into greater local control and more equitable socioeconomic outcomes.

Conclusion

This study demonstrates how ecological knowledge generated through participatory research can be mobilized to support community-based birdwatching initiatives. The integration of local ecological knowledge into ornithological surveys contributed to the development of birdwatching routes and the training of local guides, with subsequent applications in environmental education and professional guiding services that continued beyond the formal research period. Beta diversity analyses further revealed complementary bird assemblages across the sampled habitats, highlighting the potential value of considering species composition alongside richness when planning birdwatching itineraries and conservation activities. The continued use of the routes and the involvement of trained local guides illustrate how collaboratively generated ecological knowledge can find practical applications over time, although the factors sustaining community participation and the distribution of socioeconomic benefits remain to be investigated. Overall, our findings provide empirical evidence of how participatory ecological research can connect biodiversity knowledge with locally implemented environmental initiatives.

Declarations

Generative AI Disclosure

ChatGPT (OpenAI) was used to assist with language editing and reference checking. All AI-assisted suggestions were reviewed by the authors, who retain full responsibility for the manuscript's content.

Author Contribution

GB and RF contributed equally and share first authorship. Both contributed to conceptualization, methodology, investigation, and manuscript drafting. GB also contributed to formal analysis and visualization. CNEH contributed to conceptualization, methodology, investigation, funding acquisition, project administration, supervision, and manuscript revision. BV contributed to conceptualization, methodology, formal analysis, supervision, and manuscript revision. DL contributed to methodology, formal analysis, supervision, and manuscript revision. All authors reviewed and approved the final manuscript.

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Data Availability

The quantitative data supporting the findings of this study, including the MacKinnon species lists used in the bird assemblage analyses, are available from the corresponding author upon reasonable request. Qualitative field-notebook records are not publicly available to protect participant confidentiality.

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Figures

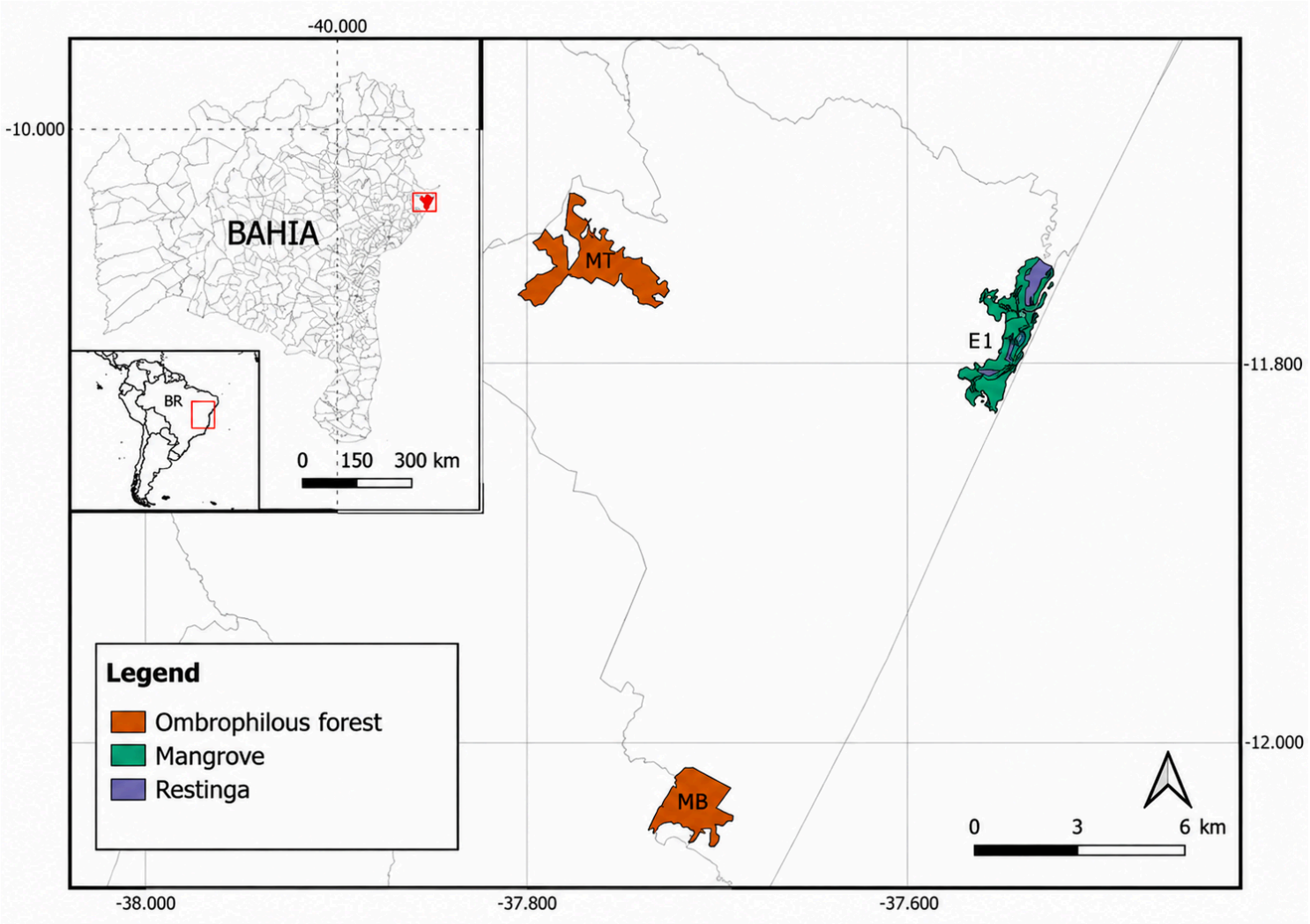


Figure 1

Location of the study area in the municipality of Conde, Bahia, northeastern Brazil, showing the sampled phytophysiognomies. Sampling sites included mangrove and *restinga*habitats in the Itapicuru River estuary (EI), and ombrophilous forest remnants at Mata do Timbó (MT) and Bú Farm Legal Reserve (MB).

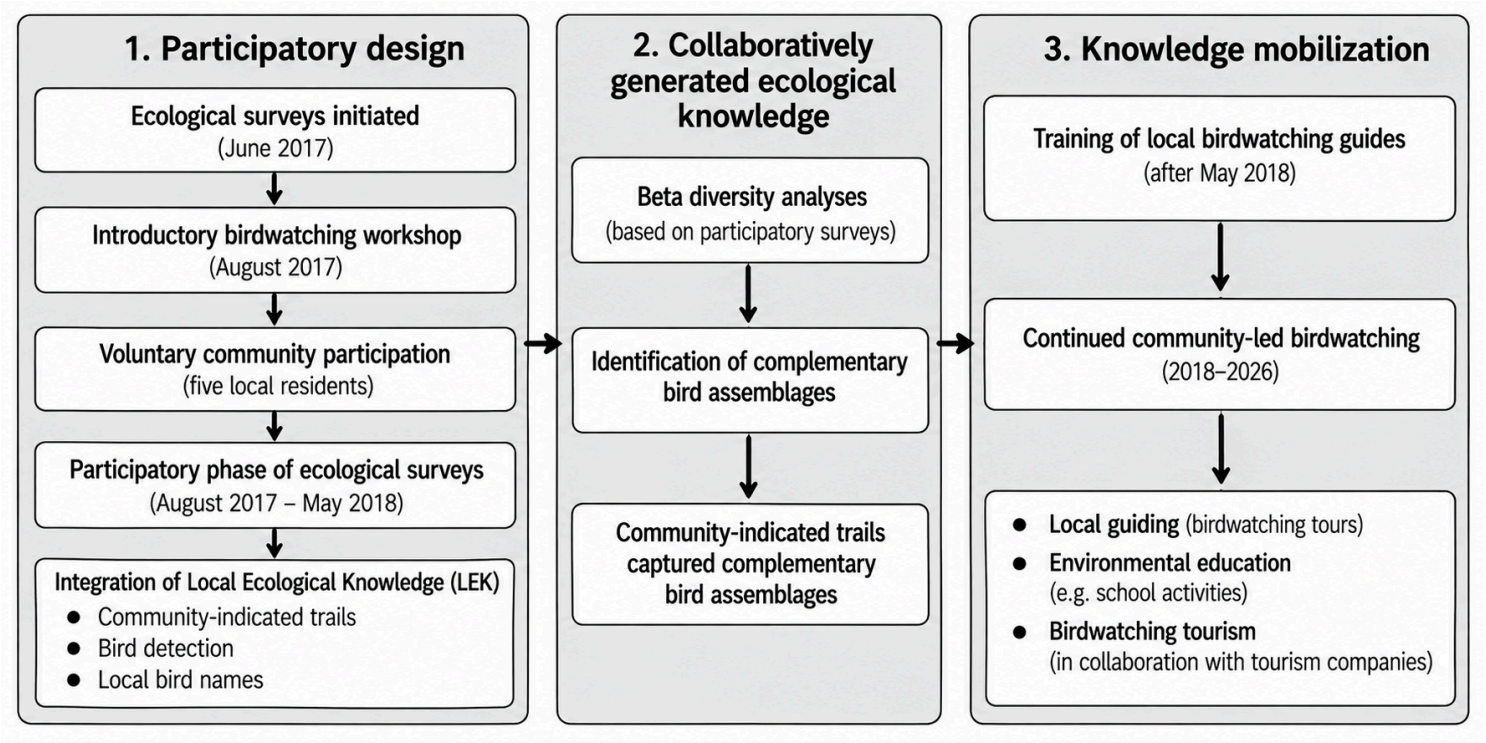


Figure 2

Conceptual representation of the pathway documented in this study, illustrating how participatory research design enabled the collaboratively generated of ecological knowledge through participatory bird surveys and the mobilization of local ecological knowledge, and how this knowledge was subsequently mobilized into a community-based birdwatching initiative.

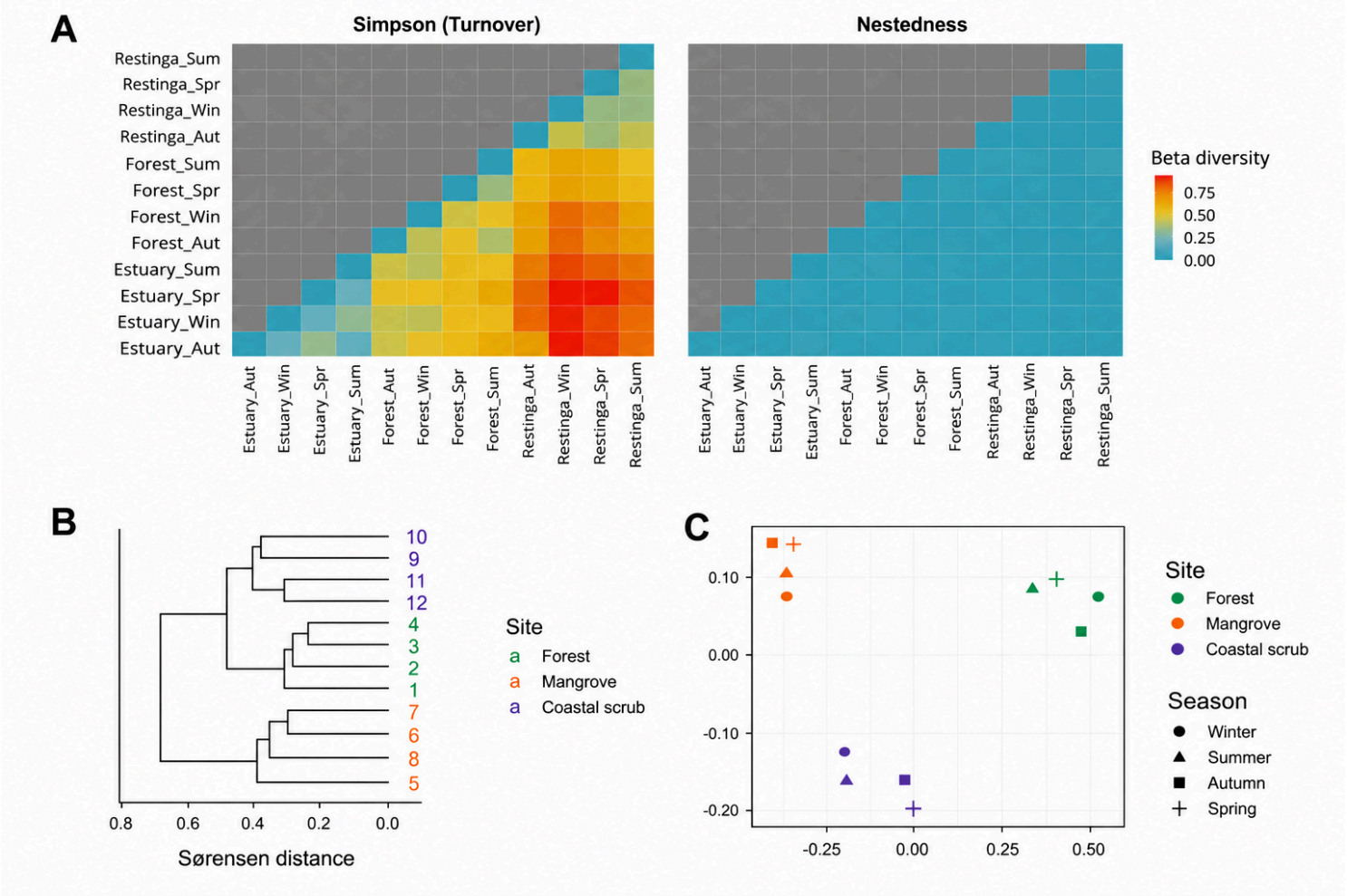


Figure 3

Patterns of beta diversity among mangrove, *restinga*, and ombrophilous forest bird assemblages across seasons. (A) Pairwise beta diversity partitioned into turnover (left) and nestedness (right). Values range from 0 to 1, with warmer colours indicating higher dissimilarity. Axis labels combine phytophysiognomies and season, where Estuary, Forest, and *Restinga* represent the sampled environments. (B) Hierarchical clustering analysis (UPGMA) based on Sørensen distance showing grouping of samples primarily according to phytophysiognomies rather than season, reinforcing the role of habitat structure in shaping bird assemblages. (C) Principal Coordinates Analysis (PCoA) based on Sørensen dissimilarity showing patterns of variation in bird species composition among sampled phytophysiognomies. The ordination reveals clear separation among phytophysiognomies, indicating strong differences in community composition, while seasonal variation was comparatively lower.

Supplementary Files

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